each other. But we have been unable to discover in these all the characters of an ovum with the same distinctness as in the preceding species, no doubt because they had not yet arrived at their complete development.

V. I have not witnessed the *deposition of the ova* in these animals. It is very probable that they escape by the anus, or by some neighbouring aperture. Thus, in the *Stylonychiæ*, I have seen them collect in the posterior part of the body which bears the anal orifice, and diminish gradually in number from the first or second day after the copulation. It is a singular thing, that about this period a round pale body begins to make its appearance in the centre of the animal; this becomes constricted about the middle, and reconstitutes the double nucleus of *Stylonychia*.

VI. The Infusoria are destitute of copulatory organs. In most cases the copulation is effected by simple juxtaposition, the two mouths establishing the sexual communication (*Paramecium, Bursaria, Euplotes, Chilodon, Spirostomum*). In the *Oxytrichinæ* the union is more intimate, and goes so far as to constitute a true soldering of the two individuals for more than two-thirds of their anterior part. Any one who had not witnessed all the phases of this singular copulation, would be unable to avoid regarding this state as a longitudinal division, proceeding from behind forwards, in a single animal. But even, if direct observation were wanting, the concomitant changes of the internal organs, which are so characteristic, cannot leave the least doubt as to the actual signification of this act.

XLVIII.—*Remarks on certain Vermiform Fossils found in the Mountain Limestone Districts of the North of England.* By Albany Hancock*.

[With six Plates.]

In 1838, Mr. Dixon Dixon, of Unthank, presented to the Newcastle Museum a few slabs of a fine-grained micaceous sandstone, which were procured from a quarry on Haltwhistle Common. These slabs exhibited on their surfaces peculiar elevated and depressed markings, supposed at the time to be either the fossil remains of worms, or casts of worm-tracks.

Slabs bearing similar markings were likewise obtained by Mr. Edward Wood, of Richmond, in 1850, from the same formation in Wensleydale, Yorkshire, and were described by that gentleman in two interesting communications published in the

* Communicated by the Author, having been read at the Meeting of the British Association held at Leeds, September 22, 1858.

1st vol. of the 'Naturalist,' in which the nature of these curious fossils is discussed, and the conclusion arrived at that they are worms, though to what order they belong is not determined. Mr. Wood, however, no longer entertains this opinion. In a letter which I had the pleasure of receiving from him a short time ago, he states that these fossils "are assuredly the track-tube or burrow of some creature, and probably, as you say, of a crustacean." And in the same communication Mr. Wood further says, "I sent a specimen to the Museum in Jermyn Street, and the lamented Edward Forbes had it marked 'Casts of Annelide-tubes,' and it is so marked still."

Shortly after the appearance of Mr. Wood's communications in the 'Naturalist,' Mr. John Dixon gave an account in the same journal of what he supposed to be another species of fossil worm, procured in the flagstone beds of Pateley-Bridge, Yorkshire, "a deposit similar in general composition to those of Wensleydale."

More recently, Mr. Howse has obtained from Weardale similar fossils; and I am indebted to that gentleman for the loan of several interesting specimens, both from that locality and from Haltwhistle.

As far as I have been able to ascertain, the papers above referred to contain all the information that has been published on these worm-like fossils of the Carboniferous system; but the prevailing opinion appears to be that they are the remains of worms, or are the casts of worm-tracks; and indeed, at first sight, their general appearance would seem fairly to justify such a conclusion. On careful inquiry, however, it appears to be untenable; and there is good reason for believing that they are the runs or tracks of crustaceans.

Some years ago, whilst walking along the beach at Cullercoats, my attention was arrested by some track-like markings on the sand, which resembled most remarkably these so-called fossil worms. So striking was the similarity, that I at once commenced an examination of them, in the hope that they might throw some light upon these enigmatical fossils; and I soon satisfied myself that the tracks on the beach, at all events, were in no way connected with worms, though, at the time, I entirely failed to ascertain how and by what they were produced. I then lost sight of the subject; and it was not until the autumn of last year, during a lengthened sojourn on the Durham coast, that my attention was again directed to these beach-markings. On this occasion I found them in great profusion on the Whitburn Sands, and in every respect similar to those previously observed at Cullercoats. They are, in fact, to be found on every sandy shore in the neighbourhood of the Tyne and Wear, occurring very abundantly on the sands at Tynemouth, Whitley, South

Shields, and Whitburn. In these localities they are to be seen everywhere between tide-marks, but are most numerous about half-way down the beach, on inclined, oozy, glistening spots, where the sand is firm, and yet the moisture so profuse that it mirrors the light.

In such situations they are very numerous and complicated. There are two or three species, the largest (Pl. XIV. fig. 1) of which is about three-eighths of an inch wide; it is slightly raised above the general surface of the beach, and is of a flattened, ribbon-like form, with a narrow median groove (*a*) running from end to end; it is occasionally several feet in length, winding in a very intricate manner, and is frequently and irregularly convoluted, forming, as it were, loose knots or systems in which neither the commencement nor the termination can be easily detected, and which are usually connected together by lengthened, slightly undulated portions of the track. The windings are, for the most part, well rounded, and in their course occasionally, but rarely, exhibit inconspicuous, arched, transverse ridges (*c*). The tracks also occasionally show enlargements placed at some little distance from each other (fig. 2 *a*); when this is the case, there is no median groove. Another variety occurs, but not frequently, in which there is neither groove nor nodulous enlargements. The extent and complication of the windings vary considerably; and though they are for the most part exceedingly intricate, as above described, they are at times found of much less extent, and comparatively simple, so that they can be followed easily enough throughout their sinuosities. At other times they may be seen, as it were, entirely unravelled, running a considerable distance in an undeviating or only slightly tortuous line.

Besides the above, another kind of track, also very abundant, is found on our shores; it is, however, very different in character, and is much smaller. It (Pl. XV. fig. 1) is in the form of a narrow wedge-shaped furrow (*a*), about two-tenths of an inch wide, with the margins occasionally a little elevated (*b*, *b*). Its windings are very capricious, irregularly rounded, frequently abruptly angulated, and sometimes for a considerable distance finely and regularly undulated or zigzagged (fig. 2). This species is often found in close proximity to the broad form previously described; but occasionally it occurs high up on the beach, and in pools and small hollows between the ripple-ridges. In such situations, however, it is not confined to the bottom of the hollows, but likewise passes up the sides of the bordering ridges.

A third variety (fig. 3) is occasionally seen, much resembling the last both in size and windings; but the furrow (*b*) is smaller

and comparatively inconspicuous, and the sand is thrown up on one side into an arched or rounded ridge (*a*), which sometimes almost obliterates the furrow. The ridge itself is frequently broken up into nodules (fig. 4), thus giving to the whole track a beaded or articulated appearance. At each articulation a puncture is occasionally observed in the furrow.

These tracks, as just described, may be observed by any one who will take the trouble to look for them; but it is not quite so easy to determine how and by what they are formed. It was long before I could ascertain these facts, and they were at length determined only after some careful watching; nothing, however, is required but time and a little perseverance. The complication and extent of the tracks are the main difficulties; on this account it is impossible to keep in view at the same time all their numerous windings, and in most cases the extremities are not to be seen. I therefore went down to the beach just as the tide was leaving the spot where the broad or first-described tracks were usually in great profusion. The sand was quite smooth, all irregularities having been obliterated by the action of the water. Here and there, however, the tracks had already made their appearance, but were as yet of very limited extent, and there was now no longer any difficulty in taking the whole in at one view, and, moreover, the extremities were perfectly distinct. It was only necessary to watch attentively to note the formation of the numerous and labyrinthine windings that had been so long a puzzle. I had not to wait long before the sand at one of the extremities was observed to be gently agitated; and on this agitation ceasing, the track was found to have added nearly half an inch to its length. In the course of two or three minutes the sand was again put in motion, and the track once more a little prolonged. These movements were repeated over and over again, until it was quite clear that the tracks were formed by slow, intermitting steps, and not, as might have been supposed, by one continuous, gliding motion. Having satisfied myself of this, I took up the morsel of sand at the end of the track, just as it was again becoming agitated, and found that I had captured a small crustacean, the species of which was unknown to me, though in general appearance it was not altogether unlike the common sandhopper, but not quite so long. It was undoubtedly one of the Amphipoda. I soon took in this way five or six specimens, all of the same species, and all forming tracks of precisely the same character,—namely broad, slightly elevated, flattened, and grooved.

Whilst forming its track, the animal is never seen; it moves along a little beneath the surface of the sand, which it pushes upwards with its back; and the arch or tunnel thus formed

partially subsides as the creature passes forward, and, breaking along the centre, the median groove is produced.

I now turned my attention to the narrow or furrowed tracks, and in the same manner took several specimens of another species of crustacean, much smaller than the first, but having some general resemblance to it. This species, like the former, makes its track step by step, resting some little time between each advance, but differs from it in having its back exposed to view while moving; on account of its colour, however, it is very difficult to distinguish from the sand.

The captured individuals were placed in a shallow vessel with the bottom thickly covered with sand moistened with sea-water, so as to resemble as nearly as possible the state of the beach where the tracks are found; and I soon had the satisfaction of seeing them make their tracks or runs in a state of confinement, thus making assurance doubly sure. The tracks so formed were precisely similar to those seen on the beach; but in one instance an interesting modification was observed. I was watching the movements of an individual of the larger species, when all at once it thrust itself through the surface of the sand, and sinking immediately again, left there an oval swelling; and repeating this action five or six times, formed a series of nodules (Pl. XIV. fig. 2 *b*), which, if continued, would have produced a track of a peculiar articulated appearance, much resembling on a large scale the nodulous or beaded form already noticed as sometimes occurring in a variety of the narrow, furrowed kind.

Specimens of the two crustaceans which make these runs have been submitted to Mr. C. Spence Bate; and he obligingly informs me that the larger one (that which makes the broad, elevated tracks) is a scarce animal, and was described by him, under the name of *Bellia arenaria*, in the 'Annals of Natural History' for 1851; but the name was afterwards changed to that of *Sulcator arenarius*. He alludes to its habit of making tracks in the sand. The smaller animal he states to be an undescribed species of the genus *Kröyera*, for which he proposes the specific denomination of *arenaria*. Both species will be figured and described by that gentleman in the 'Transactions of the Tyneside Naturalists' Field Club' for 1858.

It has been already pointed out that the tracks, which we have just seen are made by these crustaceans, are remarkably similar to the vermiform impressions observed on the Carboniferous slabs. Indeed, the broad raised track (Pl. XIV. fig. 1) produced by *Sulcator arenarius* so closely resembles some of the fossils, that it is difficult to say in what they differ. The description previously given of the former might, in fact, do very well for

the latter; only they are rarely so complicated. There are four kinds of these fossil tracks.

The first (Pl. XVIII. *c, c, c*) is in the form of a simple furrow, with a narrow ridge on each side; it is small, measuring scarcely more than one-eighth of an inch wide, and has a wandering, undulating course, which, however, is never very much complicated, and is confined to the same horizontal plane.

The second, which is a little wider than the above, is smooth, cylindrical, and tortuous, and usually remains in relief on the lower slab, but occasionally dips a little beneath the surface.

The third (Pls. XVI. & XVII.) is irregularly cylindrical, and though sometimes much undulated, is never convoluted or very complicated; it is not strictly confined to the same horizontal plane, but frequently sinks a little below the surface. Full-sized specimens are half an inch wide, and are composed of a series of nodules (*a, a*), which give them an articulated appearance. The nodules, which vary a little in size, are usually about half an inch long, and are not very symmetrically or regularly formed; consequently the surface has generally an imperfect or worn character. The extremities are not often seen; they are abruptly and irregularly rounded. This is the form more particularly described by Mr. Wood, who has in his possession the fine specimen figured in Pl. XVI., which measures nearly eight feet in length, though neither extremity is perfect.

The fourth form (Pl. XVIII. *a*), which seems to be the dominant one in Northumberland, and is that figured and described by Mr. John Dixon, is, as far as I have been able to ascertain, usually in relief upon the upper surface of the lower slab, from which it never deviates; it is considerably depressed, grooved (*b*) or ridged (Pl. XIX. fig. 1 *a*) along the middle line, and is occasionally very long. The specimen figured in Pl. XVIII. measures upwards of six feet in length, but was probably much longer, for the extremities are not present. In fact, it has not yet been determined to what length these fossils extend, as none hitherto measured have had both ends perfect. Large specimens are frequently an inch wide, and generally much undulated, and occasionally, but never intricately, convoluted. Such have the surface most frequently marked with numerous, regular, rather fine, transverse striæ or arched ridges (Pl. XIX. fig. 2), which are sometimes very delicate and close-set, though they vary in these particulars, and are occasionally coarse and irregular, giving to the whole surface a wrinkled appearance. Small specimens (fig. 1), on the contrary, are frequently wound up in an intricate manner, the folds being well rounded and often convoluted; but the surface is never marked with transverse lines or wrinkles.

It is this last form, particularly the smaller and more complicated variety, that so closely resembles the track of *Sulcator arenarius* (Pl. XIV. fig. 1). The folds or windings are precisely similar, and so is the median groove. It differs chiefly in being occasionally much larger, and in rising up more boldly in relief from the matrix, though in these respects they sometimes closely approximate. Dimensions, however, can be of very little consequence; for of course the larger the animal, the larger the track. The relief may also be influenced by other conditions; the quality of the substance in which the tracks are made must likewise be taken into account.

The crustacean, as we have seen, forces itself onward immediately beneath the surface of the sand, which is thrust up by its back, and as it moves along, a sort of arched tunnel is thus formed; but as the sand is incoherent—unmixed as it is with any material that could give it consistency—the roof falls in immediately the animal ceases to give it support, and ultimately the relief of the track is very small. As the arch falls, it must either break along the centre or thrust out the sides; the latter is impossible—hence the median groove. Had the beach been composed of sand with a large admixture of argillaceous matter or tenacious mud, it is very obvious that the tunnel would have had a greater tendency to retain its original form, and that, had it been submerged before it had subsided to any great extent, such an infiltration of matter might have taken place as to prevent any very extensive collapse. The roof, under such circumstances, would split along the centre, and the margins of the fracture would either fall inwards and form a groove, or be pressed outwards and become a ridge. It is also possible to conceive that the substance composing the shore might be so tenacious that the roof of the tunnel would scarcely subside at all, and that consequently there would be no fracture along it, and therefore neither groove nor ridge.

Now, these cases, which are hypothetical so far as they concern our crustacean tracks, do not appear to be so in regard to the conditions that prevailed during the deposition of the Carboniferous rocks which have revealed to us these curious vermiform fossils. The rocks from which the Yorkshire specimens were procured are, Mr. Wood says, "apparently equivalent to the flagstone beds placed by Phillips, in his section of the hills about Howes, low down in the middle group of the Yoredale series, and called by him the flagstone beds of Howes." And, in speaking of the nature of these flagstones, Professor Phillips states, in his work on the 'Mountain Limestone District of Yorkshire,' that they are formed of "a laminated rock, composed of small worn grains of quartz, mica with or without felspar,

and other minerals, occasionally calcareous, carbonaceous, and argillaceous: the mica or carbon, lying in particular planes, causes the minute fissility of the stone; and bands of mica or argillaceous matter separate it into thin flags or beds. The tops and bottoms of gritstone rocks are often thus laminated; plates becoming very sandy change to flagstone; grit rocks becoming very argillaceous assume the same character." It would thus appear that these fossiliferous slabs, which are composed of a finely-laminated, shaly, compact, close-grained, micaceous sandstone, contain argillaceous matter. The slabs from Northumberland have exactly the same composition, and apparently belong to the same series of rocks. It is fair, then, to assume that the matter composing these flagstones was originally of a more tenacious consistency than the sand of our shores, and therefore, were the tracks found on the slabs made by even the very same crustacean that occurs on our coast, some differences might be expected to exist between such tracks and those formed on the beach.

Such differences, we have seen, are very slight, and may all be accounted for in this way. The greater tenacity of the material at once explains the higher relief of the fossil, the occasional substitution of a ridge for the median groove, and the deficiency of either groove or ridge in those whose relief is so excessive as to have become almost cylindrical. A similar smooth variety, as previously stated, sometimes occurs on the beach; but this arises from the fact of the crustacean having tunneled deeper than usual, and in this case the relief is not great. Smooth tracks are also found on the slabs, arising, probably, from the like cause.

The specimens described by Mr. Wood are characterized, as we have seen, by a remarkable nodulous or articulated appearance (Pl. XVI. *a, a*), which has been supposed to indicate the presence of rings of some Annelide; and, indeed, were it not for the light derived from the crustacean tracks on our shores, it would not be easy to conjecture a more plausible explanation. We have seen, however, that a variety of the track of *Kröyera arenaria* has the ridge of sand thrown up broken into nodules, giving to it a beaded character. This, on a small scale, has a considerable resemblance to these nodulous forms. But a much nearer approximation is found in the nodulous tracks of *Sulcator arenarius*, particularly of the one made in confinement (Pl. XIV. fig. 2 *b*). Had the animal continued to form its track in this manner, the resemblance to those on the slabs would have been almost complete. It may therefore be assumed that the animal which made those nodulous tracks, like our small crustaceans, pushed along in its path step by step, resting awhile after

each advance,—but that, instead of moving in the same horizontal plane, it alternately rose and sunk a little; consequently a series of nodules was produced, and the track acquired its peculiar articulated appearance. This explanation is strengthened not a little when we look at the side view of the cast of the track (Pl. XVII. fig. 2). The nodules are then distinctly observed to be imbricated, and to pass, very much inclined, right through the substance from top to bottom.

We see in the ridged variety of the track of *Sulcator arenarius* another approximation to the nodulous form; at *c*, Pl. XIV. fig. 1, a few of the transverse ridges of this variety are represented, from which it will be seen that the articulated appearance is very slight, and it is pretty obvious that it is produced by the intermitting progress of the animal—the transverse arched elevations or ridges undoubtedly indicate the successive steps in the creature's path. These ridges, too, have much the character of the transverse striæ or wrinkles that cover the surface of most of the larger fossils; and it seems not altogether impossible that the latter were produced in the same manner, though they are much more closely set. It is more probable, however, that these ridges in the fossil were caused by the crumpling of the roof of the tunnel as the animal pressed forward with a short, jerking motion. And here it must be borne in mind that these transverse ridges, which in some individuals are strong and well-defined, and even coarse and irregular, in others are exceedingly delicate, and are occasionally entirely wanting. This is usually the case on slabs dark with excess of carbonaceous matter, indicating that the sedimentary material of which the rock is composed was light and incoherent; consequently the specimens on such slabs are not only devoid of those peculiar ridges, but are also in very low relief, some being quite as little elevated as the tracks on the sea-beach.

The cast of the nodulous track occasionally detaches itself entirely from the matrix (Pl. XVII. fig. 2). Mr. Wood informs me that a blow with a hammer is very liable to separate the specimen from the rock, leaving a cast on both the upper and lower slab; and in his first paper he remarks, "If the appearances above spoken of are but markings, how could they show a circular form on both the upper and lower surfaces?"

This at first sight seems a formidable difficulty; and were the tracks such mere superficial markings as is there supposed, this objection would be fatal to the view now taken with respect to the nature of these fossils. It has been shown, however, that the track of *Sulcator arenarius* is a tunnel; and with the aid of this fact, the difficulty at once disappears. If the tunnel-tracks were formed in a tenacious material, such as that from which these slabs have

apparently originated, their walls, as we have seen, would not entirely collapse, but the cylindrical form would be more or less retained. It is therefore fair to suppose that the sedimentary matter, as it was being deposited, would gradually find its way into these lengthened tunnels or burrows after their submergence, and ultimately fill them up; but, the particles of such infiltrated matter having a different arrangement from those forming the general mass of the rock, the phænomenon presented on breaking it up into slabs would necessarily occur: the casts of the tracks would become isolated like the fossil remains of any organic body, or might be left in relief on either the upper or lower slab.

The nodulous form, however, differs from the broad grooved species in not keeping strictly to the same horizontal plane; it undulates slightly vertically as well as horizontally, so that the burrow is occasionally sunk entirely beneath the surface. In such cases, as the tunnel cannot be formed by thrusting up the surface, the animal must, as it presses forward, throw the excavated matter backward, filling up the tunnel, either entirely or partially, as fast as it is made. But here, too, as the particles in the interior of the tunnel must have a different arrangement from those that surround them, the cast of the track would be liable to become isolated, on breaking up the rock, in the same manner as if the burrow had been completely filled with infiltrated matter.

It is worthy of remark, that the nodulous forms, which have neither median ridge nor groove, are rarely depressed, being frequently cylindrical, and even sometimes deeper than wide. This is just what might be expected, if the explanation now given of these fossils be correct. At the junction of the nodules there are septa formed (Pl. XVII. *f*, *f*), which pass for some little distance inwards, and which may be looked upon as so many transverse arches, giving support to the walls of the tunnel. These must naturally assist in preventing their collapse, and will in this way account not only for the cylindrical form of these specimens, but also for their deficiency of median groove or ridge. Their occasional greater or less depth below the surface of the matrix must also have been favourable to the preservation of their original form.

The foregoing observations are entirely confined to the tracks having a tunnel-form. We have seen, however, that there is another kind which occasionally occurs on the slabs from Northumberland. This is the first described species (Pl. XVIII. *c*, *c*, *c*), and is, as before stated, a simple furrow with a narrow ridge on each side. It is certainly possible that this may have been formed in the same manner as the others, and that the

groove may indicate the falling-in of the roof of a tunnel; but from its great similarity to the track of *Kröyera arenaria*, it is more probable that, like it, it is a mere surface-run formed by the exposed animal ploughing its course. However this may be, its nature cannot be questioned; it is undoubtedly a track, and so closely resembles those of the crustacean as scarcely to leave room for the interrogation, Of what? It is hardly to be doubted that they belong to some animal of that class.

From the above observations we seem justified in concluding that these curious vermiform fossils are the tracks of crustaceans; but before doing so, it would be well to inquire how far they are likely to be the remains or tracks of worms, or worm-tubes, or any other organic body.

In the first place, the enormous length of the grooved and nodulous forms is rather opposed to their being the remains of worms. Of course this does not militate against their being worm-runs, though the great width they sometimes attain does not at all favour that opinion. The width of the largest specimens of the grooved form is a little over an inch, and of the nodulous species about half an inch; their length may be three, ten, or twenty times greater than the measurements before given, as none of the larger specimens, as already stated, have yet been obtained with both extremities perfect. Size alone, however, is not sufficient to debar the possibility of their having been formed by worms; but, upon such a hypothesis, how are we to account for the peculiar character of the nodulous form? It is impossible to comprehend how the nodules, which are imbricated, passing diagonally through the track, could have been produced by a worm working its way through sand, mud, or any other material whatever. With respect to the grooved form, it may also be asked, do worms or any of the Annelides ever make runs at all similar to it? I know of no instance of any of these animals making a tunnel-track immediately beneath the surface of the beach, confined to the same horizontal plane, and with an elevated, arched roof. Annelides do not move along the surface in this manner; and when they burrow, they dip downwards, making perfectly circular passages.

The small furrowed kind, for size, might very well be the track of some worm; but its close resemblance to the runs of crustaceans has already been pointed out. With regard to the small cylindrical runs, not much can be said, as they are too deficient in character to allow of any very decided opinion; only we have seen that on the beach there are elevated cylindrical tracks produced by crustaceans not very dissimilar to those in question.

Can the two former or large species be worm-tubes, or any organic body? The transverse striation on the surface of the grooved

form certainly gives to it much the appearance of some organism. An endeavour, however, has already been made to explain the nature of this peculiar character; but whether successfully or not, there is sufficient evidence to prove that these fossils are not organic. The slabs exhibiting these vermiform tracks are frequently marked with numerous small pits or punctures, which sink for a short distance beneath the surface. These (Pl. XVII. *c, c*) have somewhat the appearance of what have been termed by geologists impressions of rain-drops. In this instance, however, they are undoubtedly produced by the animals which have made some of the smaller tracks, as it is not uncommon to see the latter terminate in one of these punctures (*e, e*). Now, it occasionally happens that the large or striated fossils are perforated by these punctures; and the scars thus made are similar to those in like manner formed on the other parts of the slab. This could hardly be so, had the slab and the fossil been originally composed of two different substances,—that is, had the former been nothing but sand or mud, and the latter a worm-tube or some other organic body.

Another fact equally instructive may also be cited. The slab in the Newcastle Museum previously alluded to exhibits not only the large grooved track, but also several of the small furrowed ones; and the latter frequently pass over the former in various directions (Pl. XVIII. *c, c, c*). The nature of the small species is not likely to be disputed: it is certainly a track of some kind; and it is remarkable that it never turns aside as it approaches the large grooved form, but passes over it at once, ploughing its way exactly in the same manner as it has done on the level portions of the sandy beach. The furrow is precisely of the same character, form, and depth, whether on the slab or on the track; and the ridge thrown up on each side is in no respect dissimilar. This seems a pretty conclusive proof that this large vermiform fossil is not a worm-tube or any organic body, but is really nothing more than a track which was, in fact, originally, as it is now, composed of the same material as the slab upon which it rests; otherwise the appearances as above described could not exist.

There still remains another very conclusive argument against the organic nature of these fossils. The folds or windings of both the grooved and nodulous forms occasionally cross each other; and when they do so, the one does not lie over the other, as it must necessarily have done were they organic, but passes right through it, cutting its own path (Pl. XVII. *b*). This is still more clearly demonstrated in the fine large specimen of the nodulous form previously alluded to (Pl. XVI. *b, b*), and appears only explicable on the hypothesis of their being mere tracks. And perhaps it will now be allowed that enough has been said to establish the high probability, at least, that they were formed by

crustaceans; it therefore only remains to be ascertained whether they can be attributed to any known fossil of the Carboniferous rocks.

Mr. Howse has suggested to me that they may be the runs of Trilobites, several species of which occur in this formation. This is not by any means unlikely. It is true, I believe, that these curious crustaceans have never been found in the rocks in which these tracks occur. They are most abundant in the lower members of the Carboniferous system, though they occasionally occur higher up in the series. Professor Phillips, in his work on the 'Mountain Limestone District of Yorkshire,' gives Alston Moor as one of the localities of *Asaphus gemmuliferus*; and I am informed by Mr. Howse that he has obtained in Tynedale two or three specimens of a Trilobite from a plate bed a little above the Scar limestone of Forster's section; and he further states that the Yoredale rocks correspond exactly to the Weardale series above Stanhope, that is, from the little limestone to the Scar limestone, and that the specimens of tracks procured in Weardale are from the slaty *Hazle* immediately above the latter—a position agreeing with that of the beds in the neighbourhood of Howes. The tracks from Haltwhistle are, he likewise states, from a slaty *Hazle* just above the little limestone.

It is therefore of no great moment that Trilobites have not been found in the strata from which these vermiform fossils are obtained, since they have been procured from the associated beds. And it is a remarkable fact that no remains whatever of any organic body are found in these flagstones; yet is there not sufficient evidence to prove that life abounded in the seas from which these rocks were derived? Numerous Trilobites might have existed during their deposition, and may have perished with the other inhabitants of those seas, leaving no trace behind them, except these, as it were, footprints in the sand. Many such footprints are all that is left in the world's stony record of existences that have passed away; and so it may be with these fossil tracks.

The Carboniferous Trilobites, however, correspond very well in size to the tracks, the largest of the grooved kind of which, we have seen, is a little above an inch wide. The width of the pygidium of *Phillipsia truncatula* is stated to be eleven lines,—that of the cephalic shield would probably be a little more; therefore, if allowance be made for the thickness of the tunnel-wall, and the necessary enlargement of the calibre beyond the width of the animal, it is evident that, so far as size is concerned, the largest tracks might be attributed to this species.

The nodulous tracks are not more than half an inch wide; there can therefore be no difficulty as to size with respect to

this form. The *P. gemmulifera* has the pygidium five lines wide; so has *Griffithides calcaratus*; and two or three other species are described to be about the same size. And, moreover, the large cephalic shield, with its anterior or head-tubercle (glabella) and projecting "cover of the eyes," appears well calculated to plough its way beneath the surface of the sandy or muddy beach. And it is worthy of remark, that in some of the tracks the central portion is considerably elevated, forming the upper surface or roof into three areas—a central elevated portion (Pl. XIX. fig. 2 *a*) and two comparatively depressed lateral portions (*c*, *c*). The former, which appears to correspond to the glabella, is grooved (*b*) along the middle line; and in one or two instances this elevated portion has occurred broken up into a series of irregular nodules (*e*, *e*), as if the animal had, at each step in its progress, thrust the head upwards, bulging out the walls of the track. The lateral portions in these cases are likewise raised up into irregular ridges at each nodule.

Burmeister, indeed, in his work on the 'Organization of Trilobites*,' expresses an opinion that their habits, like their structure, resembled those of the *Phyllopoda* (a tribe of the Entomostraca), and that they "moved only by swimming in an inverted position close beneath the surface of the water, and did not creep about at the bottom, as Klöden supposed." Though their habits may have been similar to those of the *Phyllopoda*, there does not seem any good reason for asserting that there was no deviation in this respect. Indeed, the organization of the two groups differs in so many particulars, that some variation in their modes of life might naturally be looked for. The Trilobites may have occasionally swum at the surface as supposed, and also have burrowed in the mud or sand at the bottom of the water or on the beach. Season, too, may have modified their habits in these respects.

I have now, before concluding, only to express my obligations to Mr. Wood for all the trouble he has taken to furnish me with information on the subject of these remarks, and likewise for the great exertions he has made to supply specimens for illustration. My acknowledgments are also due to Mr. Howse for similar assistance.

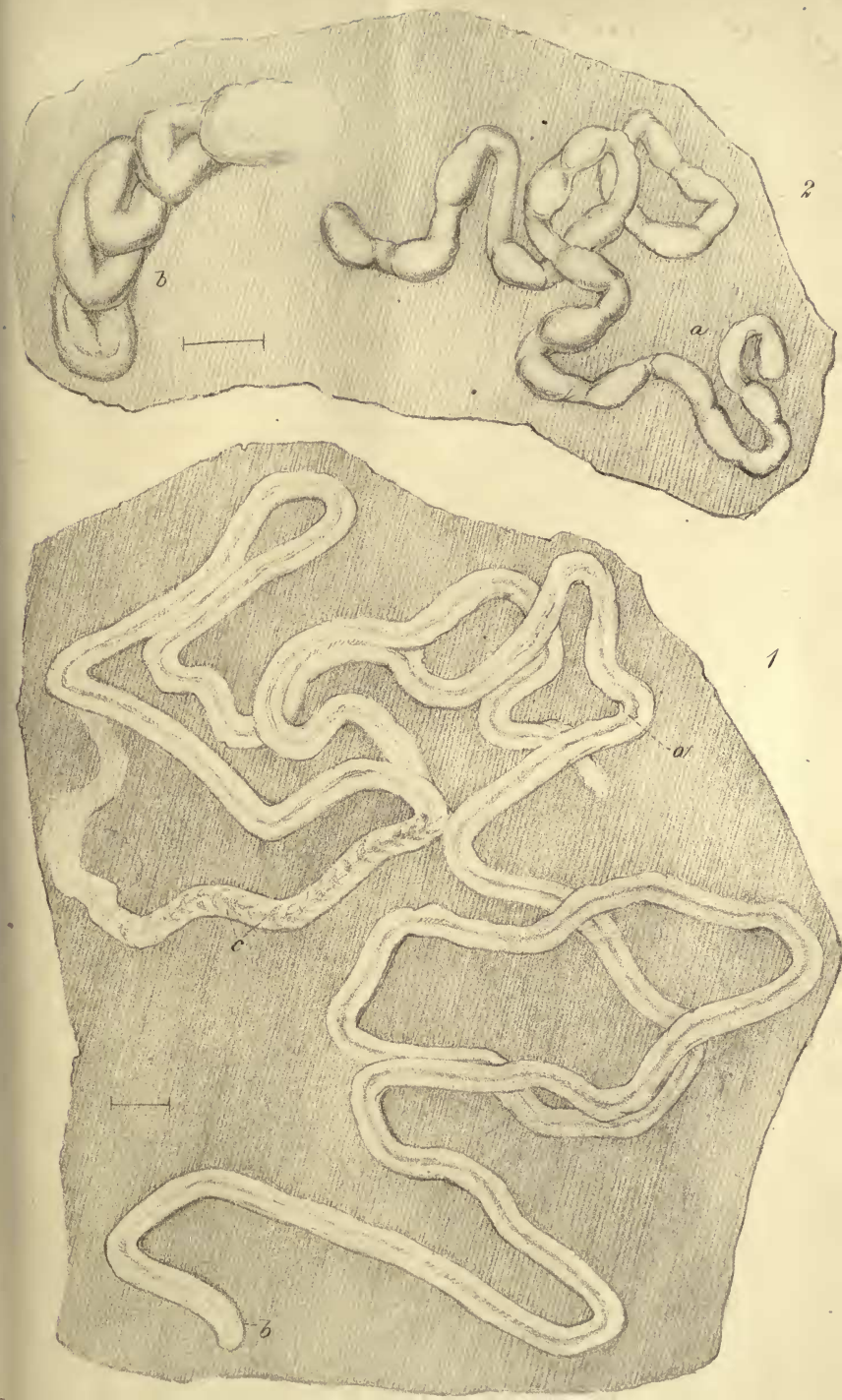
EXPLANATION OF THE PLATES.

Plate XIV.

Fig. 1. Broad, grooved track of *Sulcator arenarius*: *a*, groove; *b*, one of the extremities; *c*, inconspicuous arched ridges, which occasionally occur.

Fig. 2. *a*, Nodulous track of ditto; *b*, ditto, ditto, made in confinement.

* Published by the Ray Society.


2
b
a
1
a
c
b